arXiv:cond-mat/0409339v1 [cond-mat.mes-hall] 14 Sep 2004

Jiang *et al* Reply: In the comment by Konig, Gefen, and Silva[1], their main point is to question the approximation we used in solving the Green's function. They believe that this approximative method is inappropriate to describe spin-flip-related dephasing processes caused by intradot interaction, so they believe that our conclusions are ill-founded because of that. We agree that we indeed used an approximation in calculating the Green's function. However, we believe our approximation to be reasonable and the main conclusion, namely, an intradot electron-electron interaction can not induce dephasing, should hold.[2] In particular, we emphasize that we have taken the higher-order terms in solving the Green's function than appeared in their previous publications.[3, 4] We will compare the approximation used their papers[3, 4] with that in our work.[2]

Before we make detailed comparisons, we would first make several remarks:

(i) They and we used the same formulaes to calculate the current. Those formulaes were advanced by Meir and Wingreen.[5]

(ii) In their device as well as ours, the interaction only exists in the quantum dot (QD) and the other parts of the device should be non-interacting, so all Green functions (except $G^<_{dd}(\omega)$) can be exactly expressed using the intradot Green function $G^r_{dd}(\omega)$. This means if $G^r_{dd}(\omega)$ is obtained, then all other Green functions as well the current can be calculated straightforwardly without any further approximations.

Here we give an example to exactly express $G^r_{sk,d}(\omega)$ and $G^<_{sk,d}(\omega)$ by $G^r_{dd}(\omega)$ in our system. $G^r_{sk,d}(\omega)$ and $G^<_{sk,d}(\omega)$ are the Fourier transforms of $G^r_{sk,d}(t)$ and $G^<_{sk,d}(t)$ with $G^r_{sk,d}(t) \equiv -i\theta(t) < \{c_{sk}(t), d^\dagger_d(0)\} >$ and $G^<_{sk,d}(t) \equiv i < d^\dagger_d(0) c_{sk}(t) >$. Following the process of Phys. Rev. B **50**, 5528 by Jauho et. al,[6] we have:

$$\begin{aligned} G^r_{sk,d}(\omega) &= g^r_{sk} t_{s1} G^r_{1d} + g^r_{sk} t_{s2} G^r_{2d} \\ &= ... \\ &= \tilde{g}^r_{sk,1} t_1 G^r_{dd} + \tilde{g}^r_{sk,4} t_4 G^r_{dd} \end{aligned}$$

$$\begin{aligned} G^<_{sk,d}(\omega) &= \tilde{g}^r_{sk,1} t_1 G^<_{dd} + \tilde{g}^<_{sk,1} t_1 G^a_{dd} \\ &\quad + \tilde{g}^r_{sk,4} t_4 G^<_{dd} + \tilde{g}^<_{sk,4} t_4 G^a_{dd} \end{aligned}$$

where $\tilde{g}^{r,<}$ are the Green functions of the device decoupled to the QD (i.e. with $t_1 = t_4 = 0$) and they can be solved exactly. Similarly, all other Green functions can also be expressed using $G^r_{dd}(\omega)$ and $G^<_{dd}(\omega)$. Moreover although the Keldysh Green function $G^<_{dd}(\omega)$ in general can not be expressed by $G^r_{dd}(\omega)$, $\int d\omega G^<_{dd}(\omega)$, that is actually needed in the calculating current, can be expressed by $G^r_{dd}(\omega)$. For example, in their paper,[4] they get this relation by using $I_L + I_R = 0$ [see their Eq.(3.8) and (3.11)]. In our paper,[2] we can obtain the corresponding relation at large Γ case by using the steady state condition.

(iii) By using those exact relations among the Green functions, the current can be expressed solely by the intradot Green function $G^r_{dd}(\omega)$. In their paper,[4] they give those expressions [see their Eq.(3.9) and (3.12)] as:

$$\begin{aligned} I^{(0)}_R &= -\frac{4e}{h} \frac{\Gamma_L \Gamma_R}{\Gamma_L + \Gamma_R} \int d\omega Im G^{r(0)}_{dd} (f_L - f_R) \\ I^{(1)}_R &= \frac{4e}{h} \sqrt{\Gamma_L \Gamma_R} |t_{ref}| \cos\varphi \int d\omega Re G^{r(0)}_{dd} (f_L - f_R) \end{aligned}$$

where $I^{(0)}_R$ and $I^{(1)}_R$ are the zeroth-order (t^0_{ref}) term and the first-order flux-dependent (t^1_{ref}) term, respectively. $G^{r(0)}_{dd}$ is the zeroth-order term of G^r_{dd}, i.e. $G^r_{dd} = G^{r(0)}_{dd} + G^{r(1)}_{dd} t_{ref} + G^{r(2)}_{dd} t^2_{ref} + ...$ While t_{ref} is very small, G^r_{dd} is almost same with $G^{r(0)}_{dd}$. In our work, we use different approach. We calculate G^r_{dd}, then other Green functions, and at last the current. We emphasize that those two approaches are essentially the same.

Now we compare the approximations used in their work and ours in calculating the Green function $G^{r(0)}_{dd}$, or G^r_{dd} for a very small t_{ref}.

In our work,[2] we first exactly calculate the isolated QD Green functions $g^r_{dd}(\omega) = [\omega - \epsilon_{d\sigma} - U + U n_{\bar{\sigma}}]/[(\omega - \epsilon_{d\sigma})(\omega - \epsilon_{d\sigma} - U)]$. As a second step, we use the Dyson equation to obtain G^r_{dd}: $G^r_{dd} = g^r_{dd} + g^r_{dd} t_1 \tilde{g}^r_{11} t_1 G^r_{dd} + g^r_{dd} t_4 \tilde{g}^r_{44} t_4 G^r_{dd} + g^r_{dd} t_1 \tilde{g}^r_{14} t_4 G^r_{dd} + g^r_{dd} t_4 \tilde{g}^r_{41} t_1 G^r_{dd}$. We agree that the second step is not exact, but it is a fairly good approximation while the QD is weakly coupled to other parts of the system.

Furthermore, if only for analytical results (i) and (ii) in the first paragraph of the right column on page 3, not for the numerical calculations, we may loosen the above approximation. We may first consider that the Green functions $\tilde{G}^r$ for the system decoupled to the source and drain leads has been exactly solved. Secondly, using the Dyson equation to obtain the Green function of the whole system. Then the results (i) and (ii) on page 3 can also be obtained in a straightforward manner although $\tilde{G}^r$ is still unknown.

Next, let us examine what approximations are used in their papers.[3, 4] (i) For $U = 0$, they get $G^{r(0)}_{dd}(\omega) = 1/(\omega - \epsilon_d + i0^+)$, where ϵ_d is the intradot level. (ii) For $U = \infty$, in calculating $I^{(1)}$ they take $G^{r(0)}_{dd} = (P_0 + P_\sigma)/(\omega - \epsilon_d + i0^+) = \frac{1}{1+f(\epsilon_d)} \frac{1}{\omega - \epsilon_d + i0^+}$. (iii) For $U = \infty$, in calculating $I^{(0)}$ [i.e. to obtain Eq.(3.16) from Eq.(3.9) in Ref.[4]] they take $G^{r(0)}_{dd} = (P_0 + P_\uparrow + P_\downarrow) \frac{1}{\omega - \epsilon_d + i(\Gamma_L + \Gamma_R)/2} = \frac{1}{\omega - \epsilon_d + i(\Gamma_L + \Gamma_R)/2}$. So they do not calculate $G^{r(0)}_{dd}$ at all and they directly write down $G^{r(0)}_{dd}$ from their intuitive picture. In particular, for $U = \infty$ they use different expressions of $G^{r(0)}_{dd}$ in the currents $I^{(0)}$ and $I^{(1)}$. This is a serious error because there is only one $G^{r(0)}_{dd}$ and it can not be given two different values.

At last, we reply their other three comments. (1) They comment that $r_T > 1$ near resonance in our Fig.2 inval-

idates it as a good measure of coherence. In fact, this has been emphasized in our Letter,[2] e.g. see the paragraph after Eq.(1), or the left column of page 3, etc. We mention it here again: If only the first-order tunneling process exists, r_T describes the degree of coherence; otherwise when the higher-order tunneling processes are not negligible , r_T as well as the amplitude of conductance G_1 does not reflect the degree of coherence. In our Letter we design a system (i.e. open multi-terminal AB setup) in which the first-order tunneling process dominates, and we carry out a study of r_T in such a system. (2) They comment that our Eq.(4) is wrong, as it relies on the single-particle formalism. Notice in Eq.(4) we discuss the case of $U = 0$ [see the paragraph before Eq.(4)]. (3). They comment that $\Delta G(\phi)$ should be zero at $\phi = 0$. We made an print error in figure capture, ΔG should be defined as $\Delta G \equiv G(\phi) - G_0$. Here we also show the curves (see Fig.1 in this reply) for $\Delta G \equiv G(\phi) - G(\phi = 0)$. We gratefully acknowledge them for pointing this out.

In conclusion, all our results should hold. The e-e interaction does not induce any dephasing effect and the asymmetric amplitude does not associate with the dephasing effect.

This work was financed through Grant No.90303016 of NSFC and US-DOE.

Zhao-tan Jiang[1], Qing-feng Sun[1,*], X. C. Xie[2], and Yupeng Wang[1]
[1]Institute of Physics, Chinese Academy of Sciences, Beijing 100080, China
[2]Department of Physics, Oklahoma State University, Stillwater, Oklahoma 74078

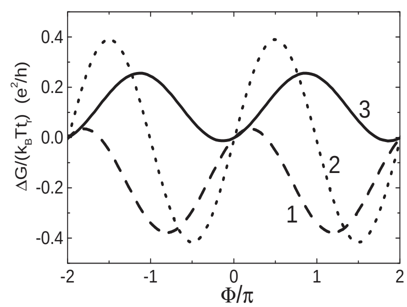

FIG. 1: $\Delta G \equiv G(\phi) - G(\phi = 0)$ vs ϕ with the same parameters as the Fig.2b in Ref.[2]

PACS numbers: 73.63.Kv, 73.23.Hk, 73.40.Gk
*Electronic mail: sunqf@aphy.iphy.ac.cn

[1] J. Konig, Y. Gefen, and A. Silva, preceding comment, Phys. Rev. Lett. ..., cond-mat/0408508.
[2] Z.-t. Jiang, Q.-f. Sun, X.C. Xie, and Y.P. Wang, Phys. Rev. Lett. **93**, 076802 (2004).
[3] J. Konig and Y. Gefen, Phys. Rev. Lett. **86**, 3855 (2001).
[4] J. Konig and Y. Gefen, Phys. Rev. B **65**, 045316 (2002).
[5] Y. Meir and N. Wingreen, Phys. Rev. Lett. **68**, 2512 (1992).
[6] A.-P. Jauho, N.S. WIngreen, and Y. Meir, Phys. Rev. B **50**, 5528 (1994).